Communications
Research Centre
Centre de recherches
sur les communications

ACCORD Broadband ATM Satellite Experiment (BASE)

-DS3 Ku-band channel

by

Isabelle Labbé, Louis Gravel, Gérard Nourry, Corey Pike, John Butterworth, Gretchen Bivens, and Brian Spink

19980602 113

CRC REPORT NO. 97-007

December 1997
Ottawa

Industry Canada Industrie Canada

The work described in this document was sponsored by the Defence R&D Branch of the Department of National Defence under work unit 5CB11.

Canada

ACCORD Broadband ATM Satellite Experiment (BASE)

-DS3 Ku-band channel

by

Isabelle Labbé *(DRX)*, **Louis Gravel** *(DRX)*,
Gérard Nourry *(DRX)*, **Corey Pike** *(DSST)*
and John Butterworth *(DSAP)*
Communications Research Centre

and

Gretchen Bivens *(Rome Lab)* **and Brian Spink** *(Rome Lab)*
Rome Laboratory

The work described in this document was sponsored by the Defence R&D Branch of the Department of National Defence under work unit 5CB11.

INDUSTRY CANADA
CRC REPORT NO. 97-007

Canada

December 1997
Ottawa

ABSTRACT

A Broadband ATM satellite Experiment (BASE) was carried out between the Communications Research Centre, Canada and Rome Laboratory, USA during the period of May 95 to March 96. The objective of the experiment was to perform a series of tests to characterize ATM over broadband satellite bearers.

This document reports on the first portion of the first phase of the experiment that was conducted in May 95 over the AnikE satellite (Ku-band). Tests consisted in measurements of ATM Quality of Service (QoS) parameters such as Cell Loss Ratio (CLR) and Cell Error Ratio (CER) as a function of Bit Error Rate (BER). In this report, the results are presented for two different modulations (QPSK and 8-PSK) and compared against theoretical curves. Results show good agreement with theory when PLCP framing is not mapped into DS-3 frames. The sub-channels have been found to be coherent with respect to each other. Experimental data further suggests that the broadband channel characteristics are similar to its embedded sub-channels. This implies that the characteristics of the sub-channels could be inferred from the broadband channel or that sub-channels results could be extrapolated to broadband channel results.

RÉSUMÉ

Une expérience de satellite MTA à large bande a été effectuée conjointement par le Centre de Recherches sur les Communications (CRC) du Canada et Rome Laboratory des Etats-Unis, de mai 1995 à mars 1996. L'objectif était de procéder à une série de tests afin de caractériser les liens satellites MTA à large bande.

Dans le présent document, il est question de la première partie de la première étape de l'expérience qui s'est déroulée en mai 1995 sur satellite Anik E (bande Ku). Les tests ont consisté à mesurer les paramètres de qualité de service MTA tels que le ratio de perte de la cellule et le ratio d'erreurs de la cellule en fonction du taux d'erreurs sur les bits. Dans ce rapport, on présente les résultats de deux modulations différentes (QPSK et 8-PSK) et on les compare à des courbes théoriques. Les résultats révèlent une bonne harmonisation avec la théorie lorsque PLCP n'est pas transposé à l'intérieur des paquets DS-3. Les sous-canaux ont été trouvés cohérents les uns par rapport aux autres. Les données expérimentales révèlent aussi que les caractéristiques des canaux à large bande sont similaires aux sous-canaux incorporés. Cela signifie que les caractéristiques des sous-canaux pourraient être déduites du canal à large bande ou qu'à l'inverse, les résultats des sous-canaux pourraient être extrapolés aux résultats du canal à large bande.

EXECUTIVE SUMMARY

Satellite communications provide an economical means for wide area and long distance communication. Both in military and civil application, their use is increasing. With the emergence of ATM, satellite links will soon be required to support broadband ATM traffic. ATM was initially designed for fibre-optic media, i.e. a random error, low delay, and virtually error free channel. Satellite channels are characterized by a long propagation delay. Moreover, the error coding scheme used to mitigate the effects of errors on the satellite channel often generates error bursts when the error correcting capability is exceeded.

The error correcting capability built into the ATM cell header performs well over fibre links but it is not expected to be adequate for satellite channels. The Header Error Correction (HEC) field of the ATM header can correct any single-bit error and can detect occurrences of two errors. Therefore, ATM performance over satellite channels needs to be analysed.

As part of the TTCP ACCORD project, the Communications Research Centre (CRC)/ Defense Research Establishment Ottawa (DREO), Canada and Rome Laboratory, USA have performed a series of tests to characterize broadband ATM satellite bearers.

The Broadband ATM satellite experiment (BASE) was divided into two phases. The objective of the first phase was to characterize broadband ATM channels and embedded sub-channels over Ku- and Ka-band satellites. The second phase aimed at characterizing the performance of standard networking protocols such as TCP/IP over broadband ATM Ka-band satellite links.

This document presents the first portion of the first phase of the experiment: the characterization of broadband ATM channels and embedded sub-channels conducted over the AnikE satellite (Ku-band). Details on the second portion of the first phase and on the second phase of the experiment can be found in documents CRC-TN-97-008 and CRC-RP-97-008 respectively.

Table of Contents

List of Figures

List of Tables

Report on Broadband ATM Satellite Experiment (BASE) -DS3 Ku-band channel

1.0 INTRODUCTION

As part of the TTCP ACCORD project, the Communications Research Centre (CRC) from Canada and Rome Laboratory from the USA have agreed to perform a series of tests related to Asynchronous Transfer Mode (ATM) over broadband (DS3) satellite bearers. The Test Plan has been presented in [1].

The objective of the first phase was to conduct Quality of Service (QoS) performance measurement of ATM over satellite links [6]. The second phase evaluated the issues associated with the provision of network services over ATM links. It characterized the performance of standard protocol pairs over ATM broadband satellite links [7].

The first phase was conducted between the 3rd of May and the 10th of May 1995 using the Anik E satellite. Section 2 of this report gives a background of ATM as it relates to satellite communication. Section 3 states the objectives of the first phase. Section 4 presents the tests performed. Section 5 gives the results obtained followed by an analysis of these results. Sections 6 and 7 consist of a list of recommendations and a short conclusion.

2.0 BACKGROUND

Satellite communications provide an economical means for wide area and long distance communication. Both in military and civil application, their use is increasing. With the emergence of ATM, satellite links will soon be required to support broadband ATM traffic. ATM was initially designed for fibre-optic media, i.e. a random error, low delay, and virtually error free channel. Satellite channels are characterized by a long propagation delay. Moreover, the error coding scheme used to mitigate the effects of errors on the satellite channel often generats error bursts when the error correcting capability is exceeded.

Furthermore, the error correcting capability built into the ATM cell header, which performs well over fibre links, is not expected to be adequate for satellite channels. The Header Error Correction (HEC) field of the ATM header can correct single-bit errors and can detect occurrences of two errors. Therefore, ATM performance over satellite channels needs to be analysed.

3.0 OBJECTIVES

This first phase was to test two configurations: one consisting of a single payload data stream which uses the entire DS-3 bandwidth i.e. 96000 cells/sec and a second configuration consisting of multiple data streams (sub-channels) with a total sum equal to a full DS-3 bearer. The primary objectives for this first phase of testing were to:

1. Characterize the DS-3 channel for transmission of ATM cells, in terms of QoS Parameters, with different modulations and error detection/correction schemes.

2. To measure the coherency of sub-channels within a broadband channel. The results of these measurements will be used to evaluate their consequences on service provisioning.

3.1 HARDWARE CONFIGURATION

The hardware configurations at CRC and Rome Laboratory were quite similar. The differences were in the satellite dish sizes, CRC used a 4.2 meter dish while Rome was equipped with a 1.8 meter dish. Also at CRC, the AdTech AX/4000 was not collocated with the EF Data modem. Figure 1 shows the system configuration at CRC.

A brief description of the equipment follows:

- AdTech AX/4000: ATM traffic generator and analyser.

- Fibre Loop Converter: converts a DS-3 signal into a single-mode fibre optic signal and vice-versa.

- EF Data Modem: generates the modulation and error detection/correction scheme for satellite communication.

- Up-Converter: transforms the 140 MHz coming from the EF Data Modem into a 14.1 GHz signal.

- Down-Converter: transforms the 11.8 GHz signal received from the satellite and converts it to a 140 MHz signal to be used by the EF Data Modem.

3.2 SOFTWARE CONFIGURATION

To meet the first objective which was to characterize the DS-3 channel, the AdTech AX/4000 was configured to generate one single channel at a rate of 96,000 cells/sec. The distribution model was configured for periodic test cells generation with a Pseudo-Random Bit Sequence (PRBS) pattern of 2E23-1. Physical Layer Convergence Protocol (PLCP) frames were embedded inside DS3 frames. PLCP is not part of the DS3 specification but can be mapped into the DS3 information payload. PLCP is part of the Transmission Convergence (TC) sublayer and is often used to carry ATM traffic over existing DS3 communication facilities.

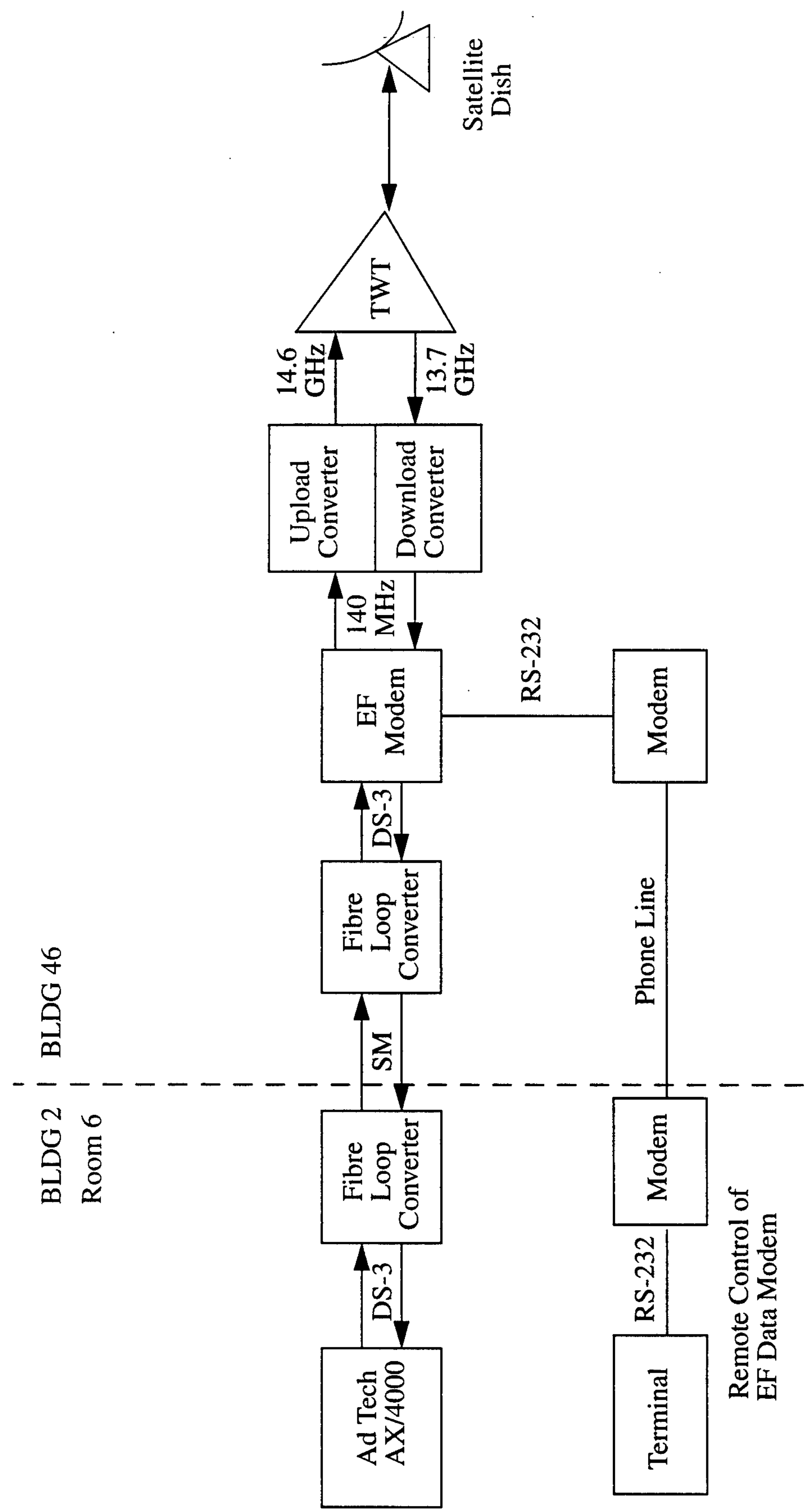

Fig 1: System Configuration at CRC

In the case of the coherency test between multiple sub-channels, the AdTech AX/4000 was configured to generate 49 streams as defined in Table 1 below. However, because of AX/4000 limitations, only two streams for each stream type (except the filler) could be analysed.

No of streams	Stream Type	Capacity (kbps)	Capacity (cps)	Total (cps)
16	DS 0	64	150	2,400
16	4 DS 0	256	603	9,648
16	DS 1	1,544	3640	58,240
1	Filler	10,900	25,712	25,712
49				**96,000**

TABLE 1. Sub-channel configuration

3.3 METHODOLOGY

Channel characterization was performed for various Bit Error Rates (BER) ranging from 10E-5 to 10E-8. The DS-3 link BER value was increased or decreased by varying the output power level of the EF modem (remotely controlled). Preceding each QoS measurements, BER readings were performed using a Data Error Analyser (Fireberd 6000 with DS3 card interface).

Throughout the tests, the following step-by-step procedure was performed:

1. Bit Error Rate (BER) measurement (using the Fireberd) with respect to calculated values (or same order of magnitude) of Table 2.
2. Record EF Modem information (Eb/No value).
3. Replace the Fireberd by the AdTech AX/4000.
4. Run the ATM test for a period of time sufficient to obtain meaningful results (see below)
5. Record the results.
6. Replace the AdTech AX/4000 device by Fireberd.
7. Take a second BER reading to ensure the BER did not drift by more than half a decade during the test period.

To obtain a valid BER reading, the sampling time period must be large enough. To calculate the time the Fireberd should run in order to have a statistically valid sampling period, the following formula was used initially:

$$\textit{Valid Sampling Time} = 100 \textit{ errors} / (\textit{BER} * \textit{Transmission Rate})$$

The 100 errors is an arbitrary value which is generally agreed to be large enough to provide a statistically valid BER value. In our case, the transmission rate was 45 Mbits/sec (DS-3). Table 1 gives the valid sampling time for specific BERs.

BER	Sampling Time
10E-5	0.2 secs
10E-6	2.2 secs
10E-7	22.2 secs
10E-8	222.2 secs
10E-9	2222.2 secs

TABLE 2. Valid Sampling Time for BER readings

After completion of a preliminary set of sub-channel configuration tests, examination of the results made us realize that the tests should be run longer to make them statistically valid. The time required for the tests were calculated using a refined formula:

$$ValidSamplingTime = 100 \bullet \frac{((53bytes)/(cell)) \bullet ((8bits)/(byte))}{TransmissionRate \bullet BER}$$

The valid sampling time for Cell Loss Ratio and Cell Error Ratio readings given by this formula are shown in Table 3.

BER	Sampling Time
10 E-5	1.5 min.
10 E-6	15 mins
10 E-7	150 mins
10 E-8	1500 mins
10 E-9	15000 mins

TABLE 3. Valid Sampling Time for AdTech AX/4000

All the experimental results presented in this report are based on these sampling time values.

3.4 TESTS PERFORMED

The tests performed are described here in a chronological order:

1. May 3, 1995: Familiarization night. No data collected.
2. May 4, 1995: Single Channel testing, half duplex, using QPSK modulation without Reed-Solomon (RS) coding.
3. May 5, 1995:Single Channel testing in loopback using 8PSK modulation with RS.
4. May 6, 1995: Single Channel testing, full duplex, using 8PSK modulation with RS.
5. May 7, 1995: Sub Channels testing, half duplex, using QPSK modulation without RS.
6. May 8, 1995: Sub Channels testing, half duplex, using QPSK modulation without RS.
7. May 9, 1995: Single Channel testing, full duplex, using 8PSK modulation with RS.
8. May 10, 1995: Sub Channels testing, full duplex, using 8PSK modulation without RS.

Note: As a result of the non-valid statistical run time period mentioned previously, tests #4 and #5 were performed again (test #7 and test #6) using the new calculated ATM sampling period.

4.0 RESULTS

For every tests described in section 3.4, the following QoS data was gathered at each receiving end:

1. Eb/No;
2. Cell Count;
3. Cell Loss Count;
4. Misinsertion Cell Count;
5. Out-of-Sequence Count;
6. Errored Cell Count;
7. Cell Rate;
8. Cell Loss Ratio;
9. Cell Misinsertion Ratio;
10. Cell Error Ratio;
11. PRBS Bit Error Ratio;
12. PRBS Bit Error Rate;
13. PRBS Sync Error Count.

The following Alarms were also noted:

1. Line Code Count and Rate;
2. Framing Count and Rate;
3. P-Bit Count and Rate;
   (P-Bit -> DS3 frame parity errors)
4. CP-Bit Count and Rate;
   (CP-Bit -> DS3 frame path parity (C-bit parity bits) errors)
5. FEBE Count and Rate;
   (FEBE -> DS3 frame far end block errors)
6. Framing Count and Rate;
7. PLCP B1 Count and Rate;
   (PLCP B1 -> PLCP bit-interleaved parity (BIP) errors)
8. PLCP FEBE Count and Rate.
   (PLCP FEBE -> PLCP far end block errors)

Due to limitations in the AX/4000 software configuration, a total of six sub-channels (out of 48) were analysed, i.e. two of each stream type (2 DS0, 2 4DS0 and 2 DS1).

5.0 ANALYSIS

For each test, Cell Loss Ratio (CLR) and Cell Error Ratio (CER) measurements are plotted as a function of BER. For comparison purposes, the analytical curves of ATM cell discard probability for burst error model and random error model are also drawn[1].

Tests which produced at least one hundred lost cells were considered valid. However, stable conditions for BERs equal or inferior to 10E-7, which required a longer test time, were often hard to get and the BER had a tendency to drift over the test period. A BER reading was taken after each QoS measurements and compared against the initial reading. If the values were more than half a decade apart, the results were declared non-valid.

Channel characterization was difficult to perform when Reed-Solomon was added (especially for the 8PSK full duplex test). Because of the steep slope (Eb/No curve) produced by the encoding scheme, few BER readings were possible. For this reason, the remaining tests were done using Viterbi coding only.

Figure 4 to Figure 23 show the CLR and CER as a function of the BER for both single channel and sub-channels. As expected the CLR in a burst-error channel is greater than in a random-error channel. However, the CLR results are greater than expected. After investigation, it was found that this anomaly can be attributed to the PLCP framing mapped

1. These computed curves were taken from the paper "ATM Operation via Satellite: Issues, Challenges and Resolutions"[2]. The analytical burst error model is based on the QPSK with Viterbi encoding. The burst error model is in accordance with the paper "ATM over Satellite: Analysis of ATM QoS Parameters"[3].

inside DS3 frames. While conducting the single channel tests, it was noted that approximately 1000 cells were lost every time a Loss Of Frame (LOF) state was declared in the PLCP statistics. According to the IEEE 802.6 standard [4], a LOF state is declared in two instances:

a. when bytes A1 and A2 are in error for more than 1 ms; or

b. when two successive Path Overhead Identifiers (POI) are in error for more than 1 ms.

Either of the two conditions above is unlikely to occur in practice. This is so since the characteristics of the EF Data modem Viterbi decoder are such that, when a decoding error occurs, an error burst lasting approximately 2 microseconds [5] is generated. This is well under the one millisecond required to trigger a LOF condition.

However, there exists another case that will cause a LOF to occur. The standard [4] states that the trailer of the PLCP frame (shown in Fig 2) used with DS3 will vary in length depending on the value of the C1 byte. Table 4 shows the possible values of the C1 byte and the respective trailer length (13 or 14 nibbles).

1	1	1	1	53 octets	13-14 nibbles
A1	A2	P11	Z6	First DQDB slot	
A1	A2	P10	Z5	DQDB slot	
A1	A2	P9	Z4	DQDB slot	
A1	A2	P8	Z3	DQDB slot	
A1	A2	P7	Z2	DQDB slot	
A1	A2	P6	Z1	DQDB slot	
A1	A2	P5	F1	DQDB slot	
A1	A2	P4	B1	DQDB slot	
A1	A2	P3	G1	DQDB slot	
A1	A2	P2	M2	DQDB slot	
A1	A2	P1	M1	DQDB slot	
A1	A2	P0	C1	Last DQDB slot	Trailer

A1: Framing Octet (11110110)
A2: Framing Octet (00101000)
P11-P0: Path Overhead Identifier Octets
Z6-Z1: Growth Octets
F1: PLCP Path User Channel
B1: BIP-8
G1: PLCP Path Status
M2-M1: DQDB Layer Management Information Octets
C1: Cycle/Stuff Counter

Fig 2: DS3 PLCP Frame Format

C1 Code	Frame Phase	Trailer Length (nibbles)
11111111	1	13
00000000	2	14
01100110	3 (no stuff)	13
10011001	3 (stuff)	14

TABLE 4. Cycle/stuff counter Codes

If the C1 byte is in error, there is a possibility that the decision on the trailer length will be incorrect, causing a misalignment of the PLCP frame. This will eventually lead to a LOF condition. Recovery from a LOF condition is implementation dependent. For the AdTech, it takes a minimum of 12 ms to remove the LOF state. During this period, all the data is lost[1] resulting in a significant increase of the CLR.

To confirm this explanation, additional tests without the PLCP framing were performed in IF loopback[2]. QoS measurements for QPSK and 8PSK are shown in Figures 24 and 25 respectively.

The QPSK results are in close agreement with the analytical curve, the CLR being now 6 to 10 times lower than the CER. The 8PSK CLR's, however, remain slightly above the curve. The difference in the coding scheme is the likely explanation for the CLR being higher for 8PSK than it is for QPSK.; however no confirmation could be obtained from the EF Data Modem manufacturer. 8PSK uses trellis coding while QPSK uses convolutional coding. Therefore, the channel modulation scheme giving the best ATM results seems to be dependent on the type of error correction coding used with the modulation scheme.

For the subchannels tests, the validity of the results for the slowest stream type (DS0) is doubtful because of the few lost cells obtained. The observation times required to measure CER and CLR at less than full DS-3 rates can be lengthy. For example, at DS0 rate (64kbps) it would have required a sampling period of ~180 hours to measure a CLR of 10E-6 if done according to the formula given in section 3.3. This is excessive especially if we consider the 8 hour testing period that was available.

There was no difference between the results of subchannels of the same stream type. There was in fact, no significant difference between stream types. The QoS measurements are almost identical for DS0, 4DS0 and DS1 (Figs 4 to 9) leading us to believe that the transmission rate is not a significant parameter for ATM QoS values at rates inferior to T1 (1.544 Mbs) and that errors are distributed proportionally to the sub-channels bandwidth.

1. Data lost = rate * recovery time = 96000cells/s * 0.012 s = 1152 cells.

2. The tests were performed in IF loopback because the ANIK-E satellite was not available.

A single test was performed with concatenated Reed-Solomon coding but the difficulty in gathering results prevents us from drawing conclusion. Based on Reed-Solomon characteristics, the following behaviour could be expected. Reed-Solomon coding provides a more robust error correction scheme by adding more data (block) to the incoming bit stream giving better QoS values. However, for a BER greater than 10E-6, the code overhead becomes more important than its error correcting capability, thus resulting in an overall negative coding gain and an associated rapid deterioration of QoS values. In this instance, Viterbi alone will give better results.

6.0 CONCLUSIONS

In this experiment, the characterization of a broadband Ku-band ATM satellite channel (45 Mbps) and its embedded sub-channels was performed. The following conclusions can be drawn:

a. The theoretical curves show that the CLR and CER values expected in burst error channels are higher than the ones expected in random error channels. Experimental data for burst error channels are in close agreement with the theory when PLCP framing is not present. The results suggest that applications using ATM over burst error channels will experience greater difficulties for a given bit error rate than it would for a random error media. The characterization of the breaking point is application dependent and has not yet been tested. To improve the cell discard ratio on a burst error channel, more error correction should be added in the ATM header. This implies modifying the standard. An alternative would be to use a bit interleaving scheme to spread the errors in the ATM cell header.

b. CLR results are higher when PLCP framing is embedded into DS3 frames.

c. The PLCP frame structure used with DS3 is not well designed to cope with burst errors. Burst errors may be a channel characteristic or may be generated when the error correction capability of the FEC is exceeded. A burst error corrupting the C1 byte can cause frame misalignment resulting in a high cell discard ratio. DS3 framing, without PLCP, should thus be used since it is expected to be tolerant to burst errors. If PLCP framing must be present, a possible solution to reducing LOF conditions would be the use of bit interleaving on the PLCP header, or part of the PLCP header that includes the C1 byte. This would reduce the probability of making a wrong decision on the PLCP trailer length.

d. When PLCP framing is absent, QPSK results are in agreement with the theory while 8PSK results remain slightly higher. Different methods of coding (convolutional vs Trellis) are likely to be responsible for this behaviour.

e. DS0, 4DS0, and DS1 sub-channels characteristics are coherent with respect to each other. This means that errors are distributed proportionally to the substreams bandwidth. Experimental data further suggest that the broadband chan-

nel characteristics are similar to its embedded sub-channels. This implies that the characteristics of the sub-channels could be inferred from the broadband channel or that sub-channels results could be extrapolated to broadband channel results. This was verified through additional testing performed during the Ka-band experiments [6].

7.0 RECOMMENDATIONS

Since this was only the first phase, the following recommendations could improve the procedures for further testing:

1. Have more measurements for BER between 10E-6 and 10E-7.
2. Lengthen the sub-channels tests to insure that at least 100 cells be lost for the DS0 stream.
3. Eliminate tests with RS because of the difficulty to get more than two or three points.
4. Perform the tests without PLCP framing mapped into the DS3 frames in order to avoid the sudden increase in the CLR.
5. Verify the coherency of the broadband channel and its embedded sub-channels over the Advanced Communication Technology Satellite (ACTS) satellite.

8.0 REFERENCES

[1] J. Butterworth, G. Nourry, "*Test Plan for an Investigation of the Transport Of ATM-Based Traffic by Ku-Band Satellite Bearers*", Ottawa, 15 Dec. 94.

[2] D. M. Chitre, D. S. Gokhale, T. Henderson, J. L. Lunsford and N. Mathews "*Asynchronous Transfer Mode (ATM) operation via satellite: issues, challenges and resolutions.*" International Journal of satellite Communications, Vol. 12, 211-222 (1994).

[3] S. Ramseier, T.Kaltenschnee, "*ATM over Satellite: Analysis of ATM QoS Parameters*", Conference records ICC '95, pp 1562-1566.

[4] ISO/IEC 8802.6, "*Physical Layer Convergence Protocol (PLCP)*", 1994.

[5] Palmer and Chang, "*Evaluating Burst Error Patterns Initiated by Viterbi Decoders*", Comsat Labs Technical Note CTD-90-041, March 15, 1995.

[6] I. Labbé, et al, "Broadband ATM Satellite Experiment (BASE) -DS3 Ka-band", CRC-TN-97-008, Ottawa, December 9th, 1997.

[7] I. Labbé, et al, "Broadband ATM Satellite Experiment (BASE) -Protocols characterization", CRC-RP-97-008, Ottawa, December 9th, 1997.

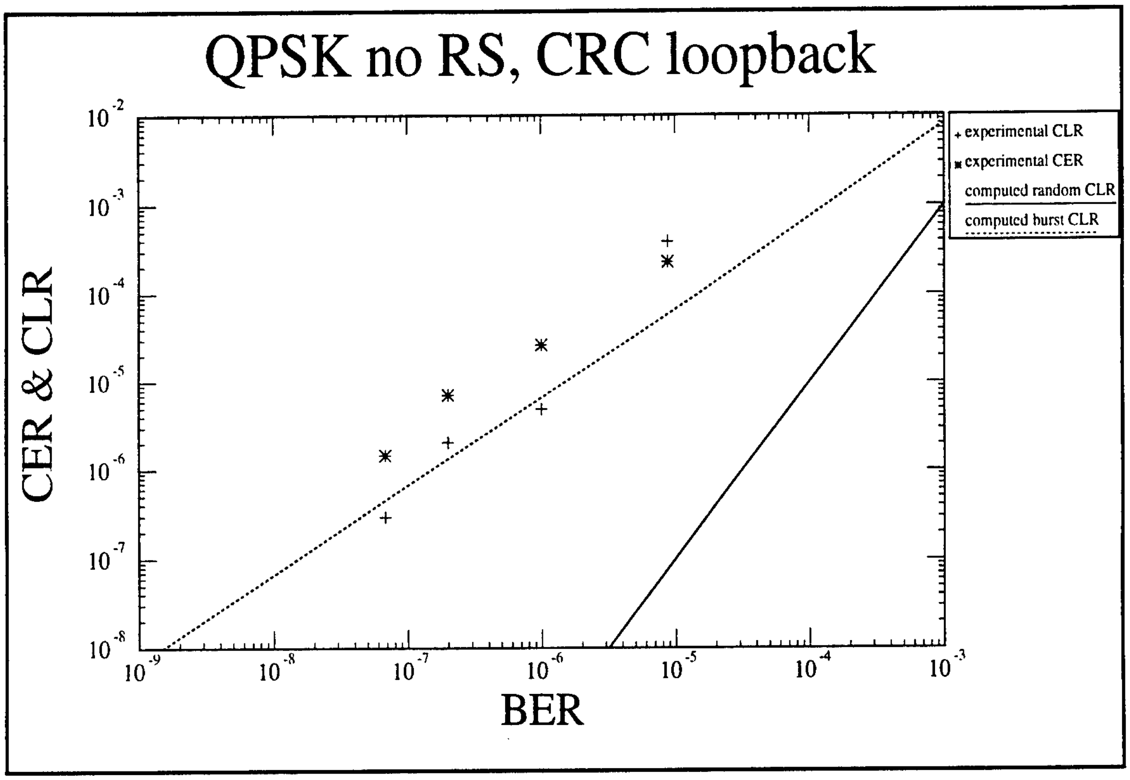

Figure 3: QPSK no RS Single channel CRC loopback

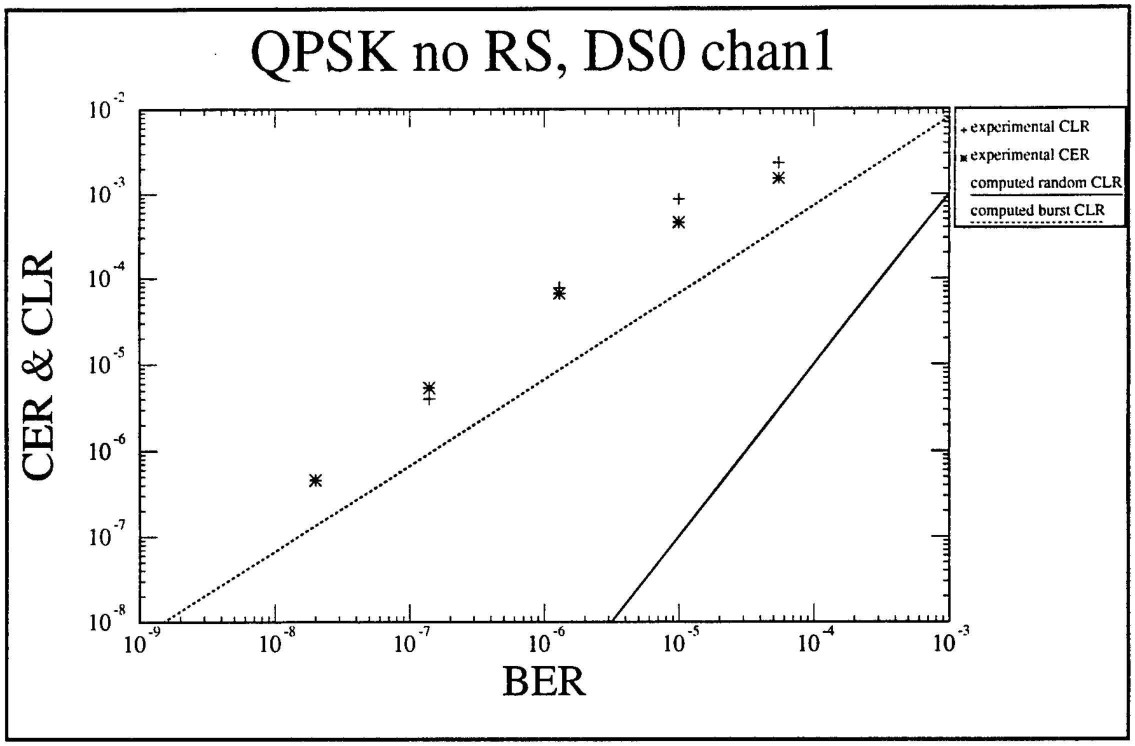

Figure 4: QPSK no RS subchannel DS0 channel 1 CRC-> Rome

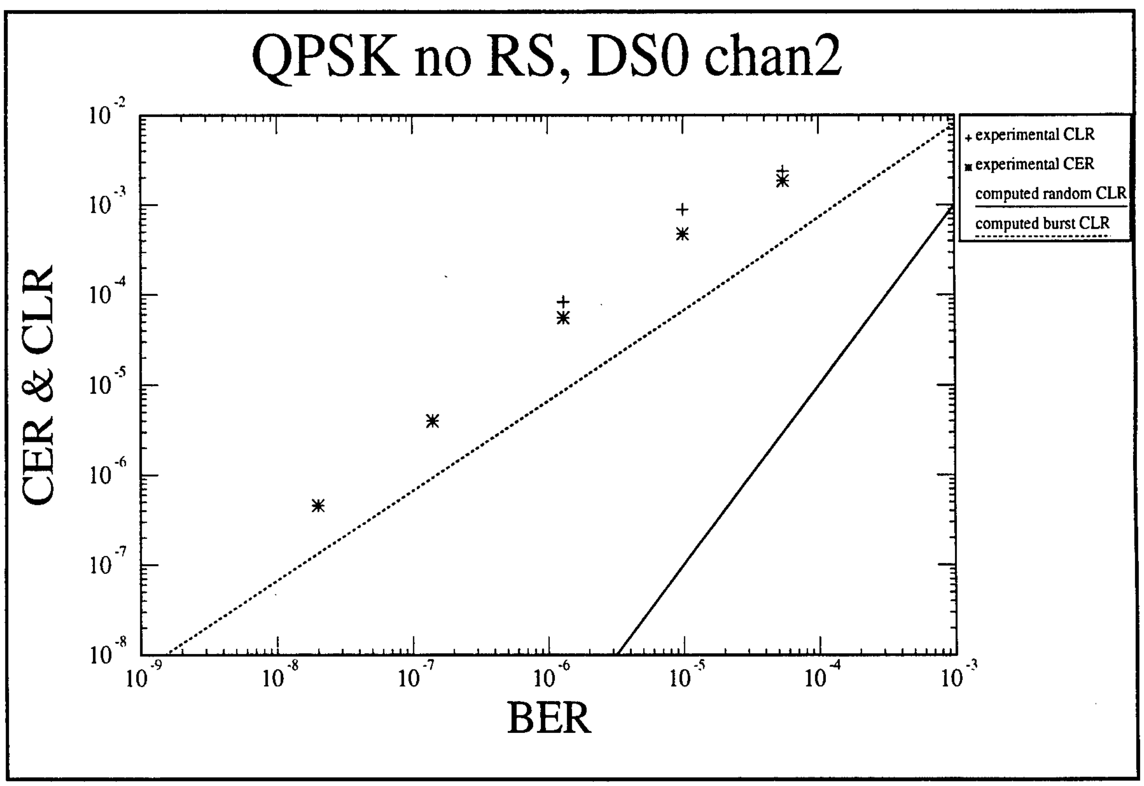

Figure 5: QPSK no RS subchannel DS0 channel 2 CRC-> Rome

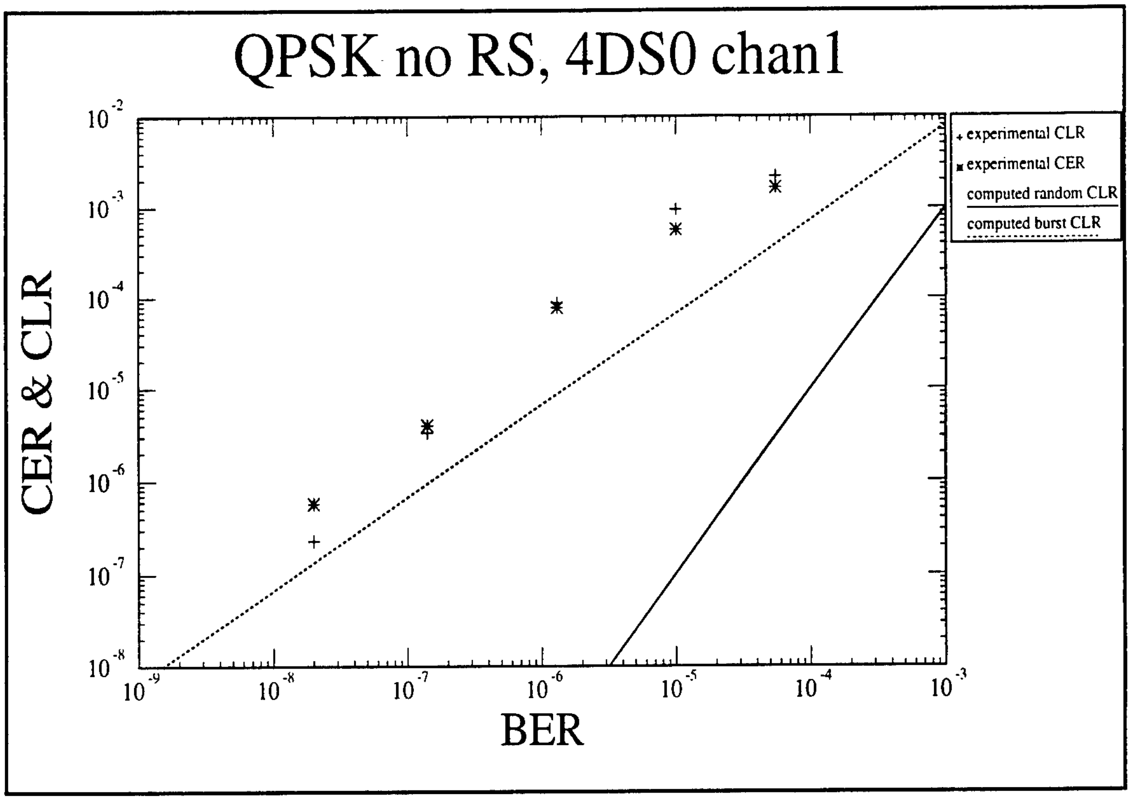

Figure 6: QPSK no RS subchannel 4DS0 channel 1 CRC-> Rome

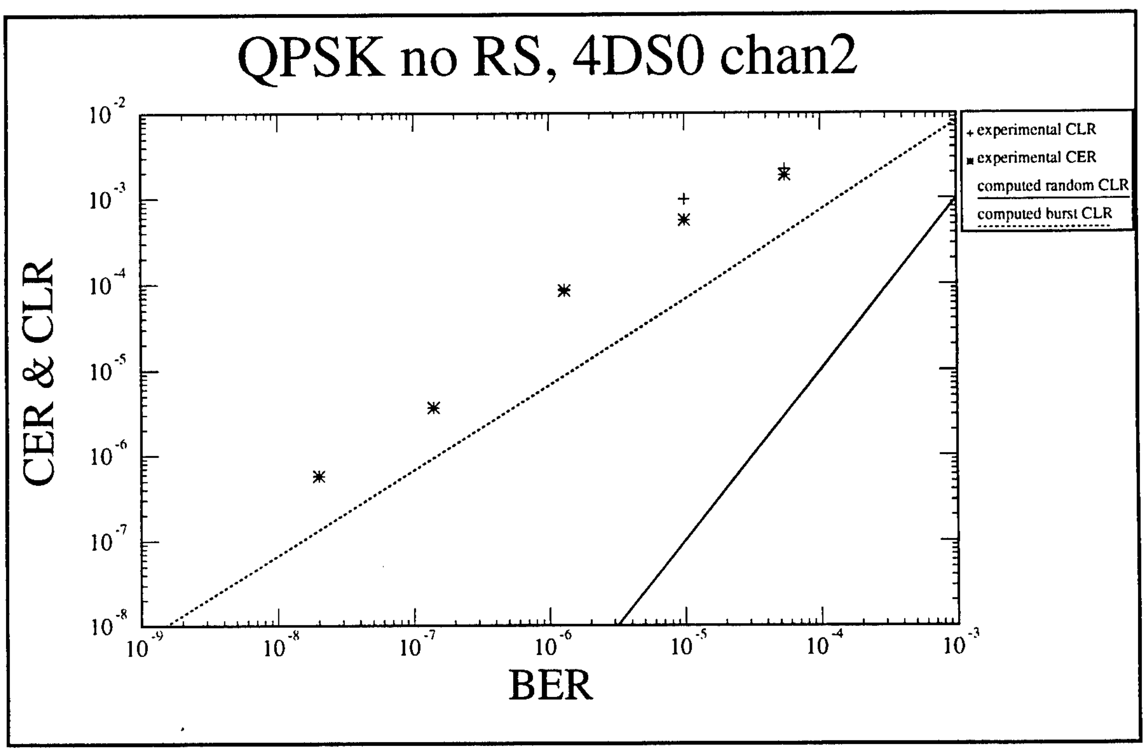

Figure 7: QPSK no RS subchannel 4DS0 channel 2 CRC-> Rome

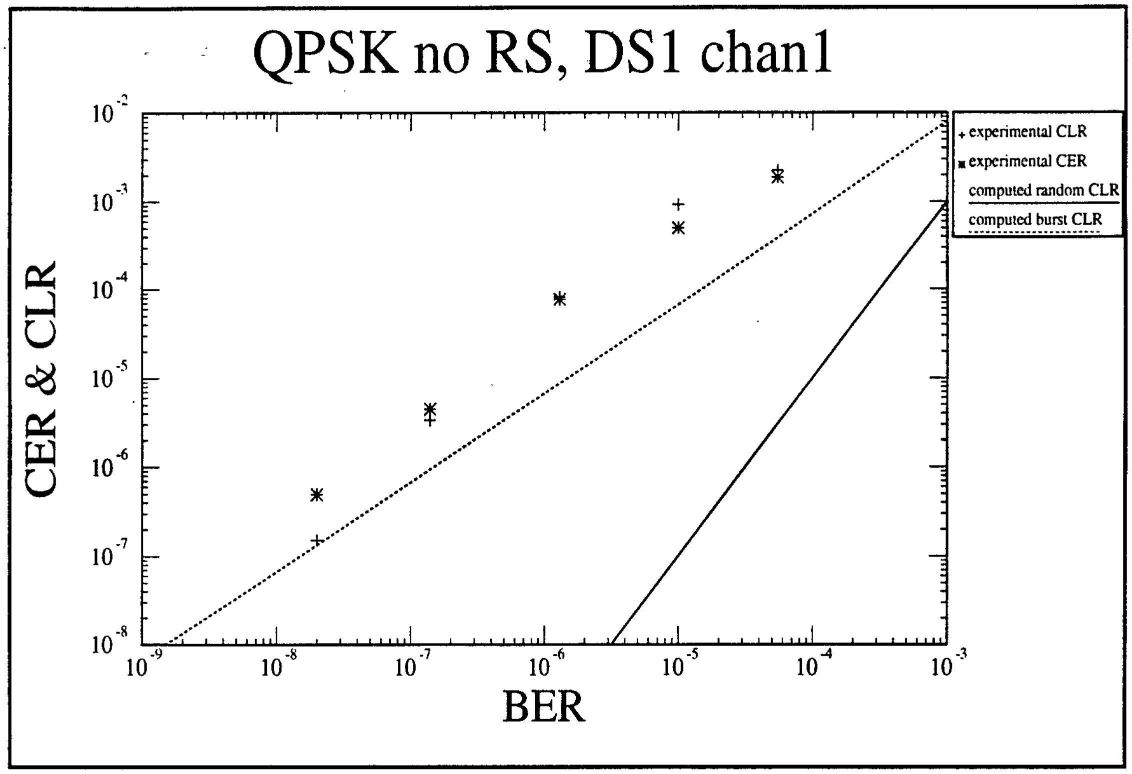

Figure 8: QPSK no RS subchannel DS1 channel 1 CRC-> Rome

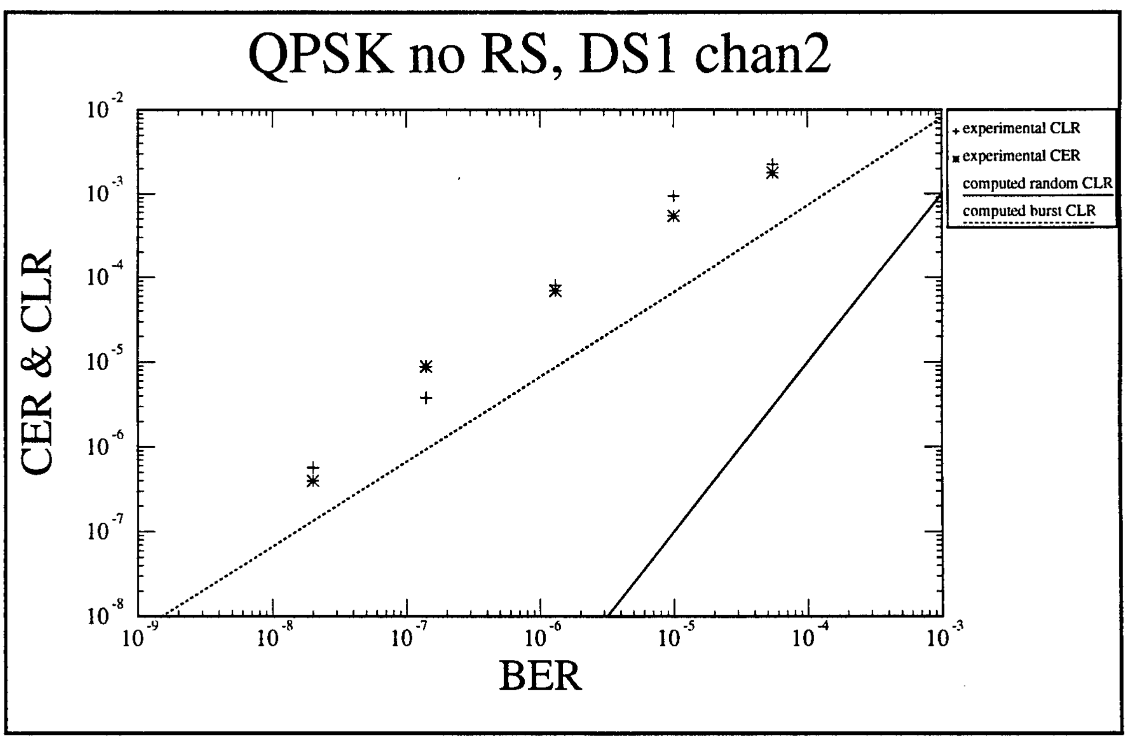

Figure 9: QPSK no RS subchannel DS1 channel 2 CRC-> Rome

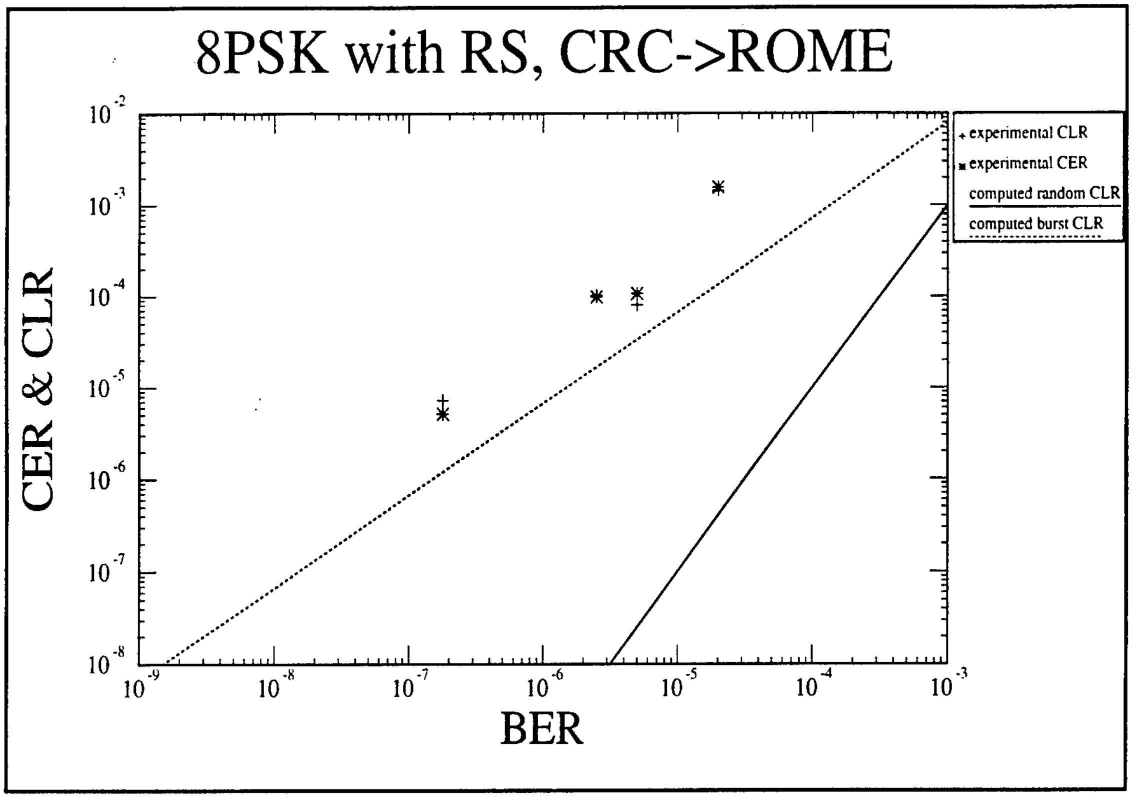

Figure 10: 8PSK with RS Single channel CRC-> Rome

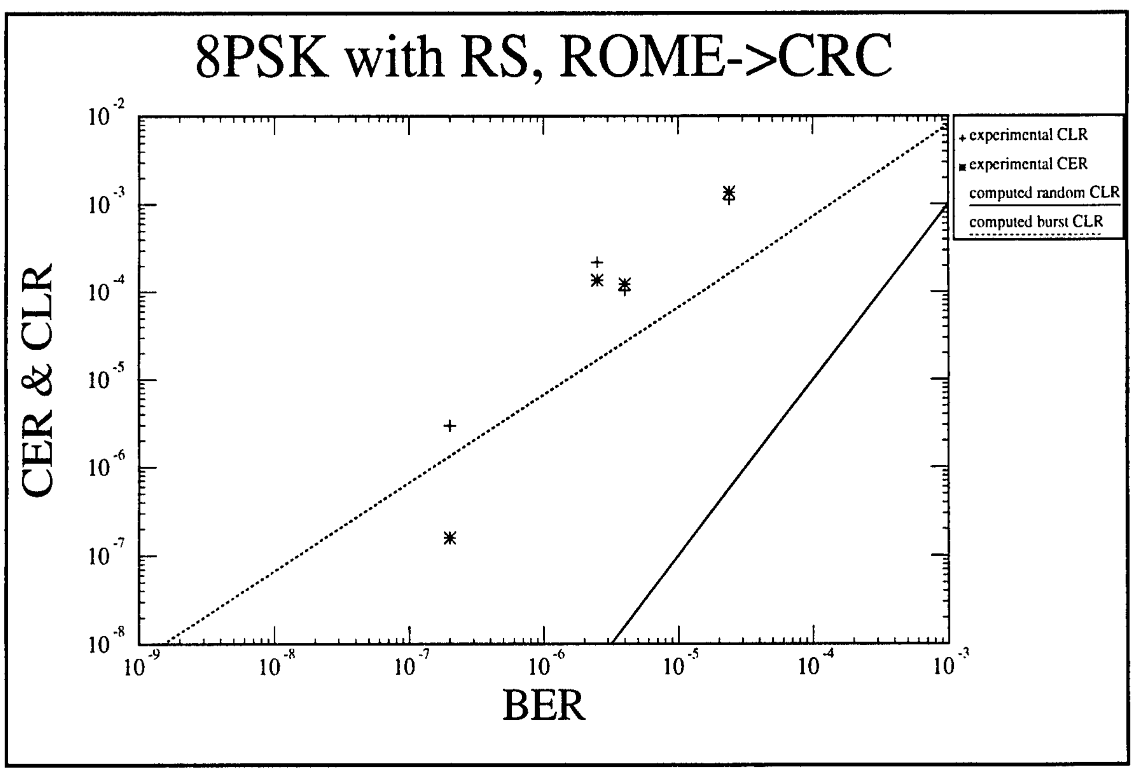

Figure 11: 8PSK with RS Single channel Rome -> CRC

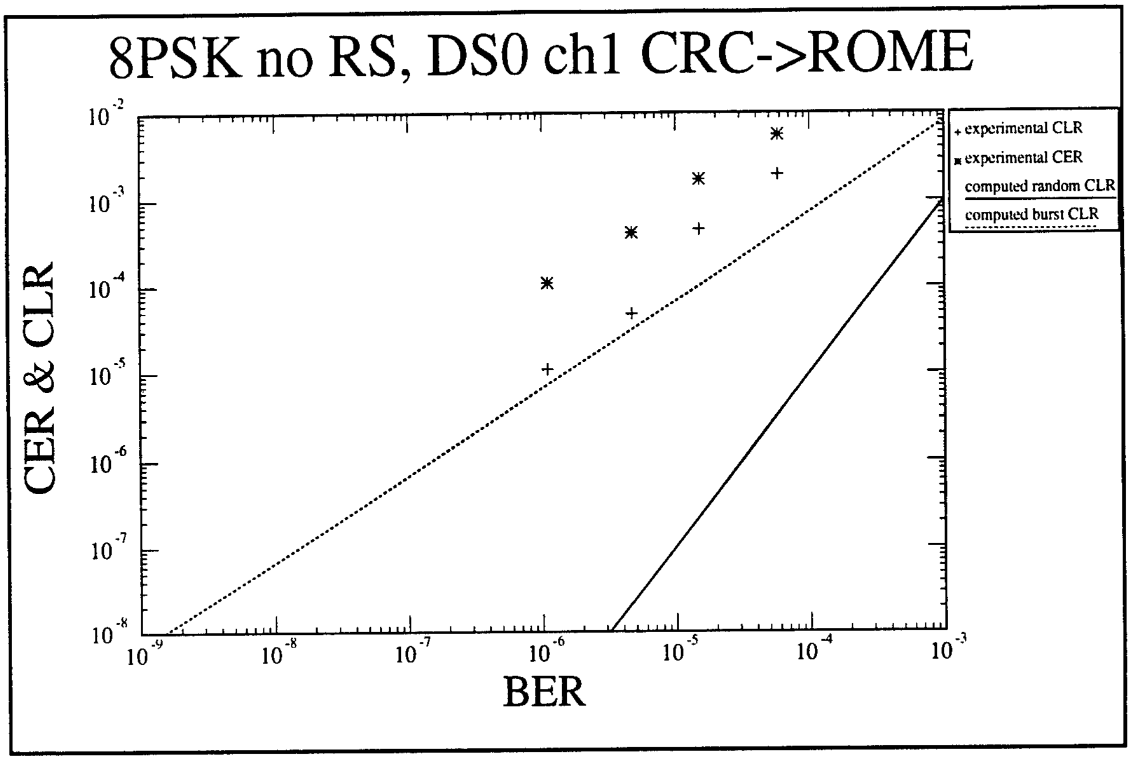

Figure 12: 8PSK no RS subchannels DS0 channel 1 CRC-> Rome

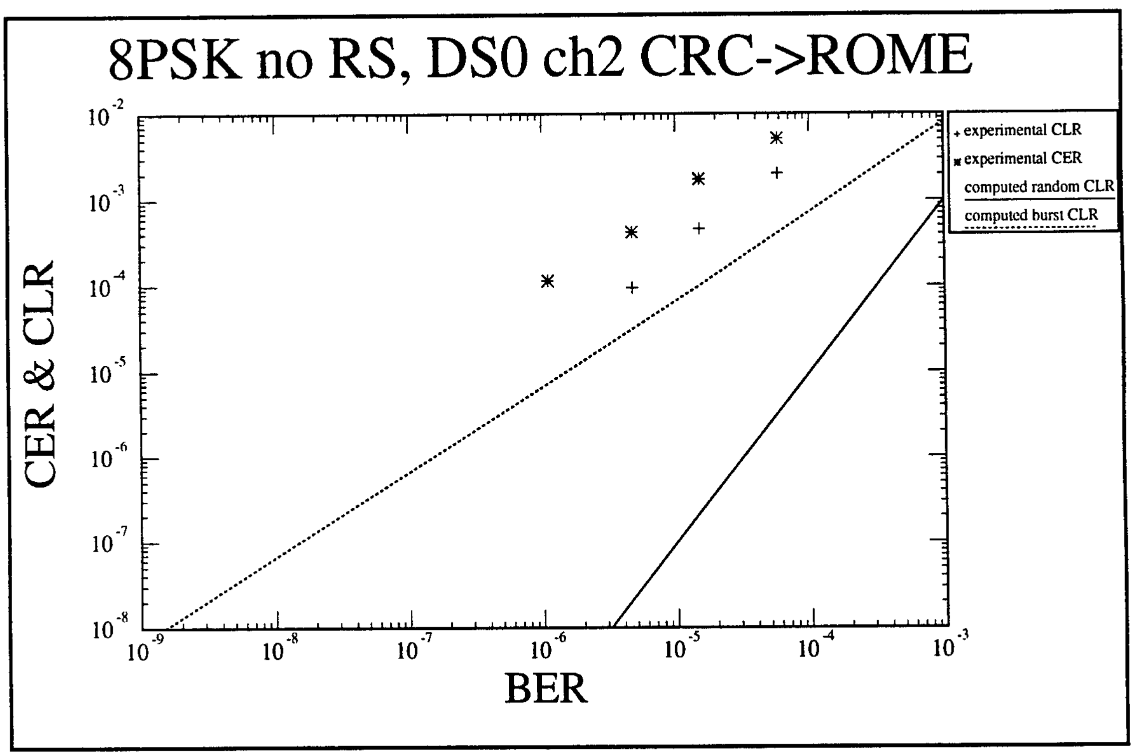

Figure 13: 8PSK no RS subchannels DS0 channel 2 CRC-> Rome

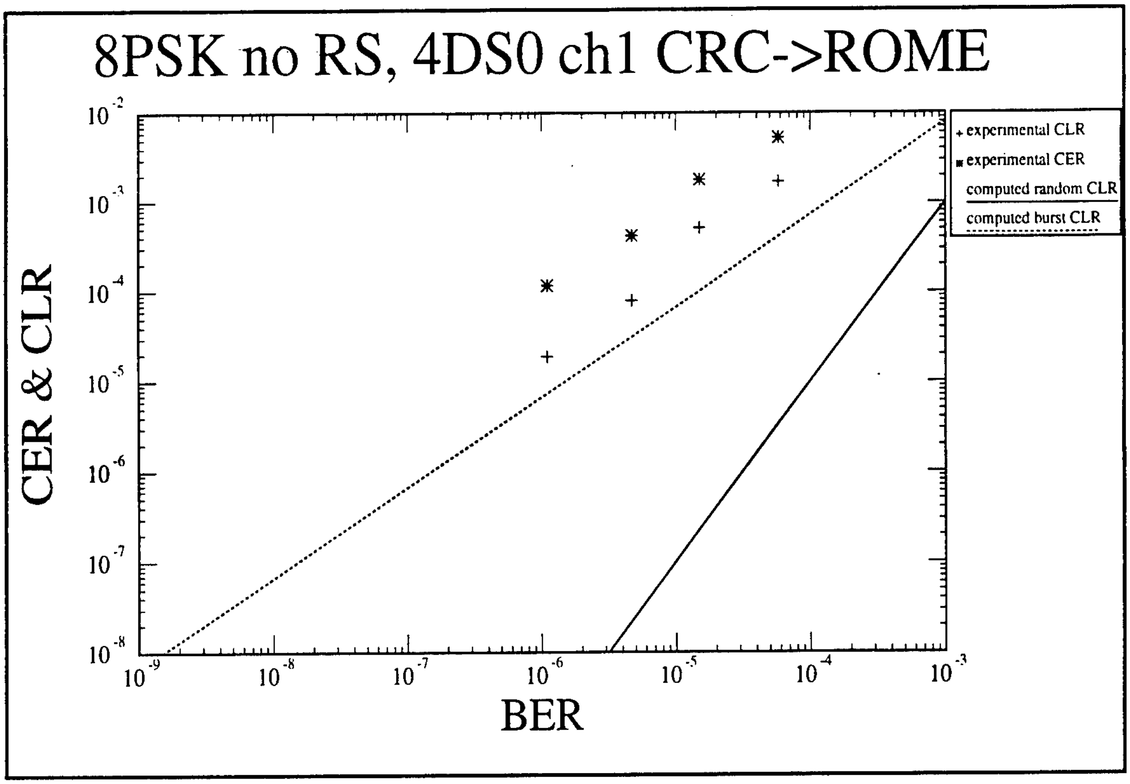

Figure 14: 8PSK no RS subchannels 4DS0 channel 1 CRC-> Rome

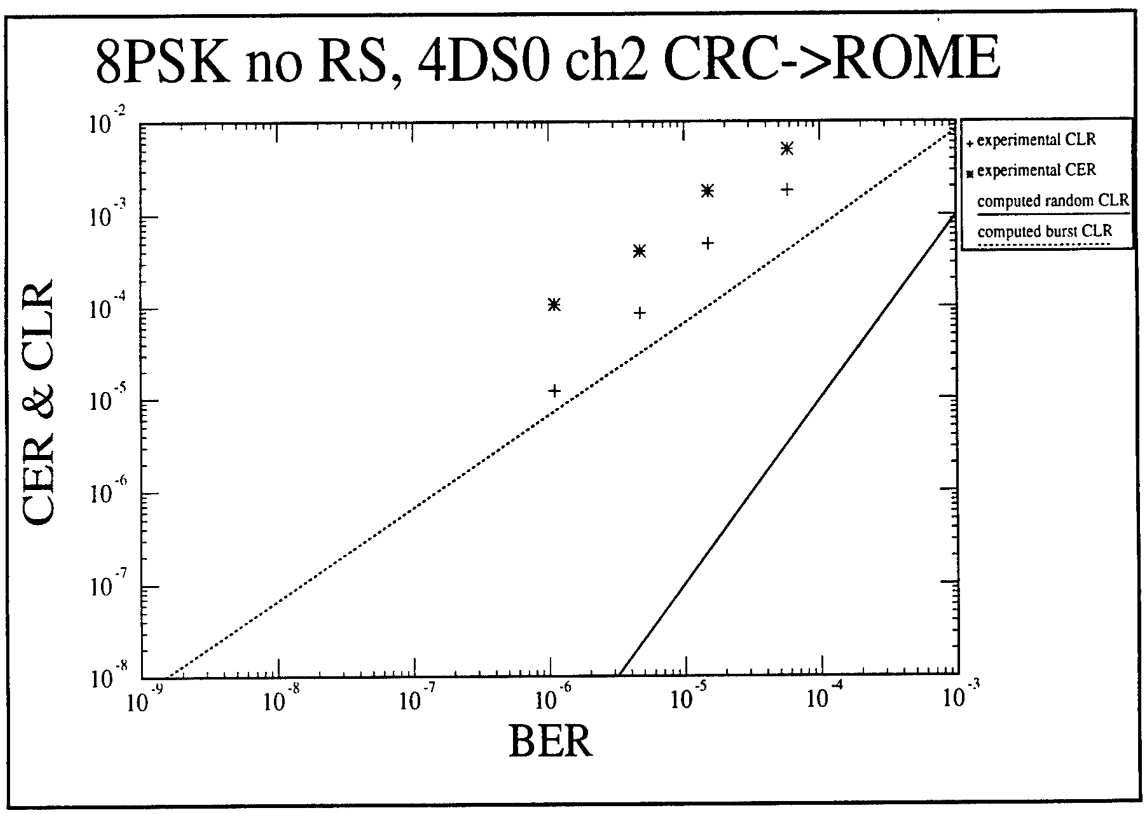

Figure 15: 8PSK no RS subchannels 4DS0 channel 2 CRC-> Rome

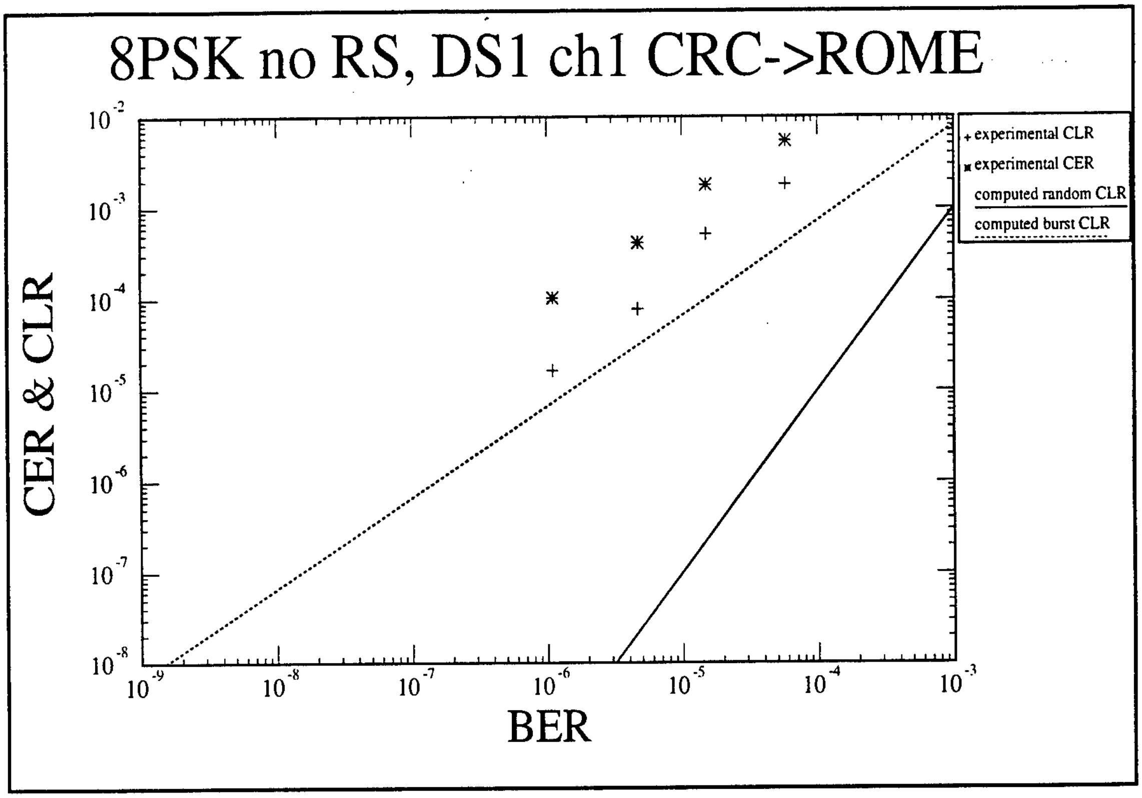

Figure 16: 8PSK no RS subchannels DS1 channel 1 CRC-> Rome

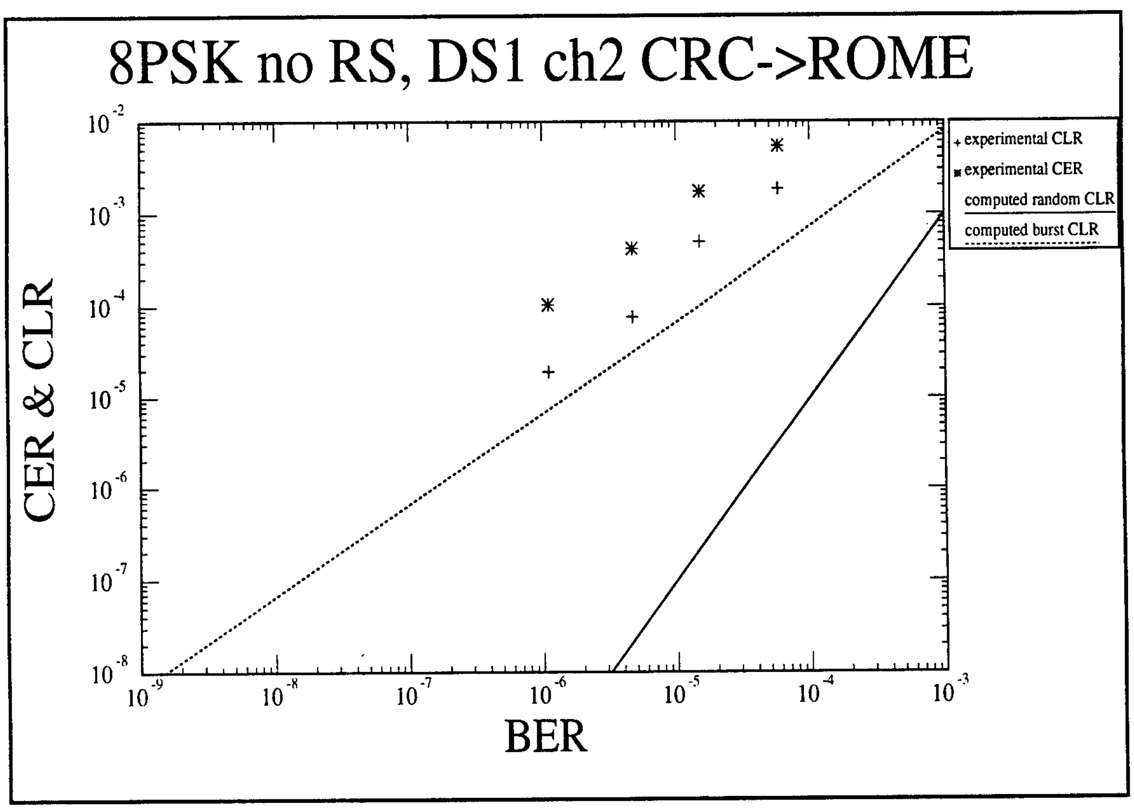

Figure 17: 8PSK no RS subchannels DS1 channel 2 CRC-> Rome

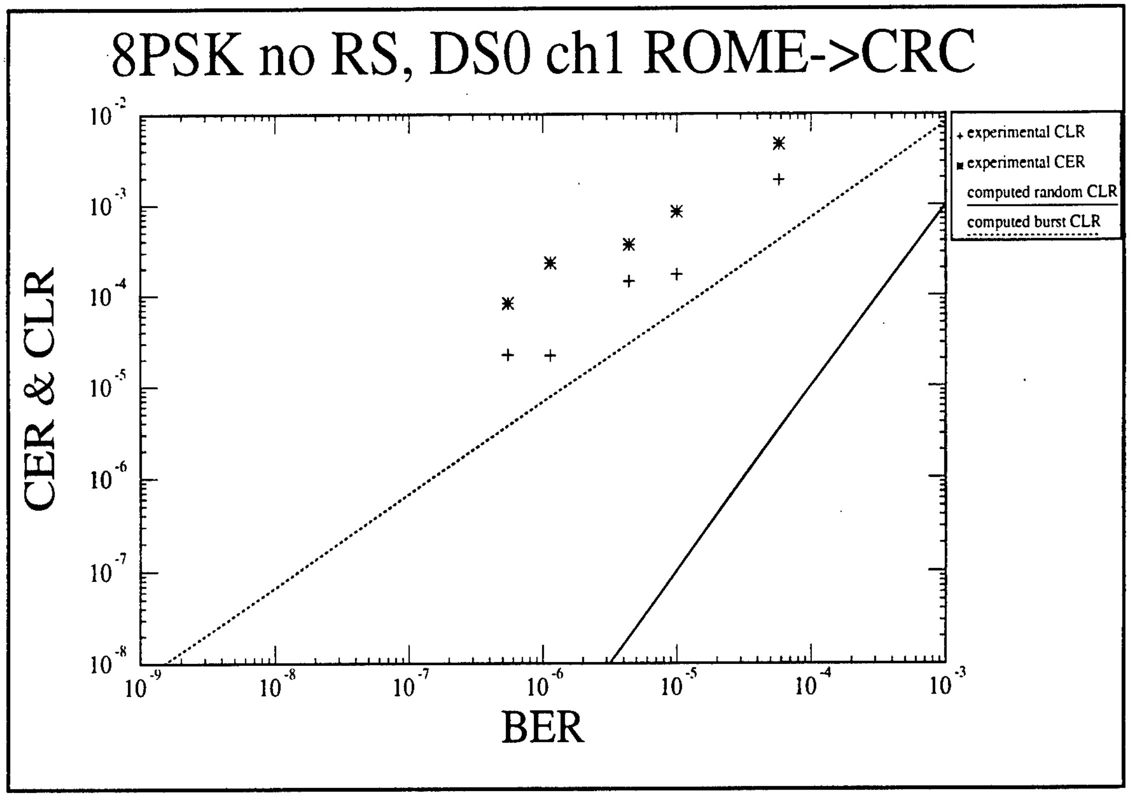

Figure 18: 8PSK no RS subchannels DS0 channel 1 Rome -> CRC

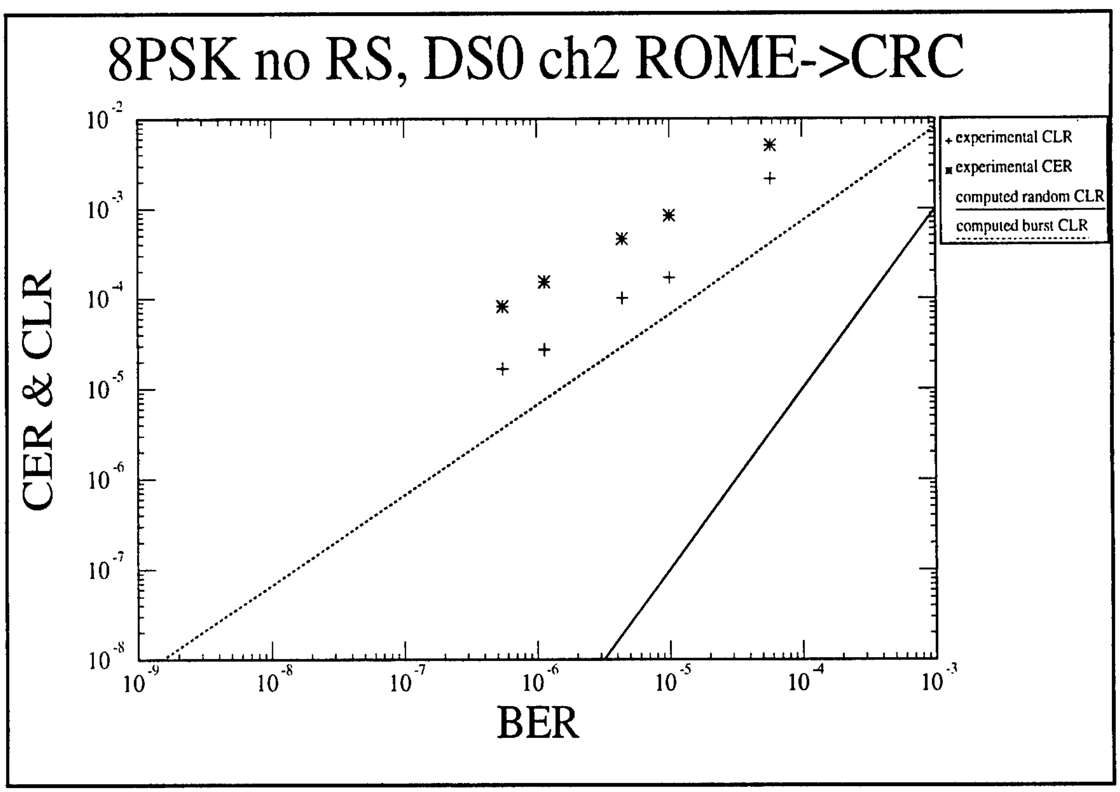

Figure 19: 8PSK no RS subchannels DS0 channel 2 Rome -> CRC

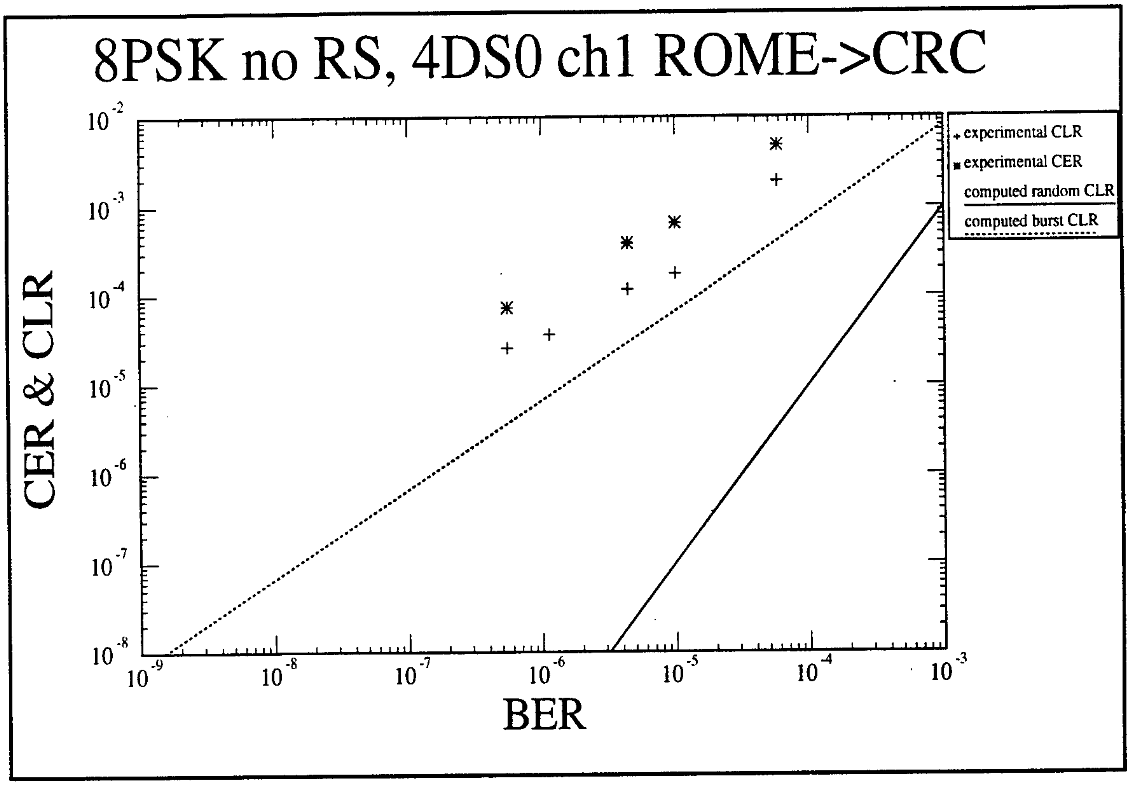

Figure 20: 8PSK no RS subchannels 4DS0 channel 1 Rome -> CRC

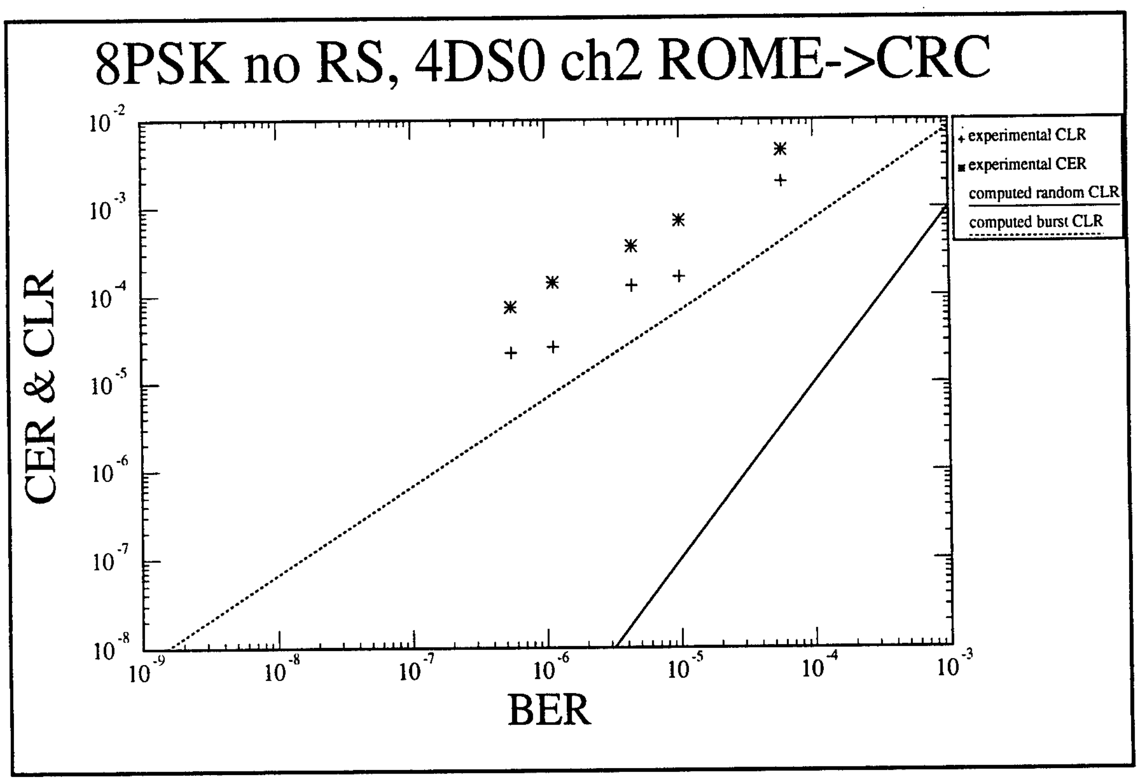

Figure 21: 8PSK no RS subchannels 4DS0 channel 2 Rome -> CRC

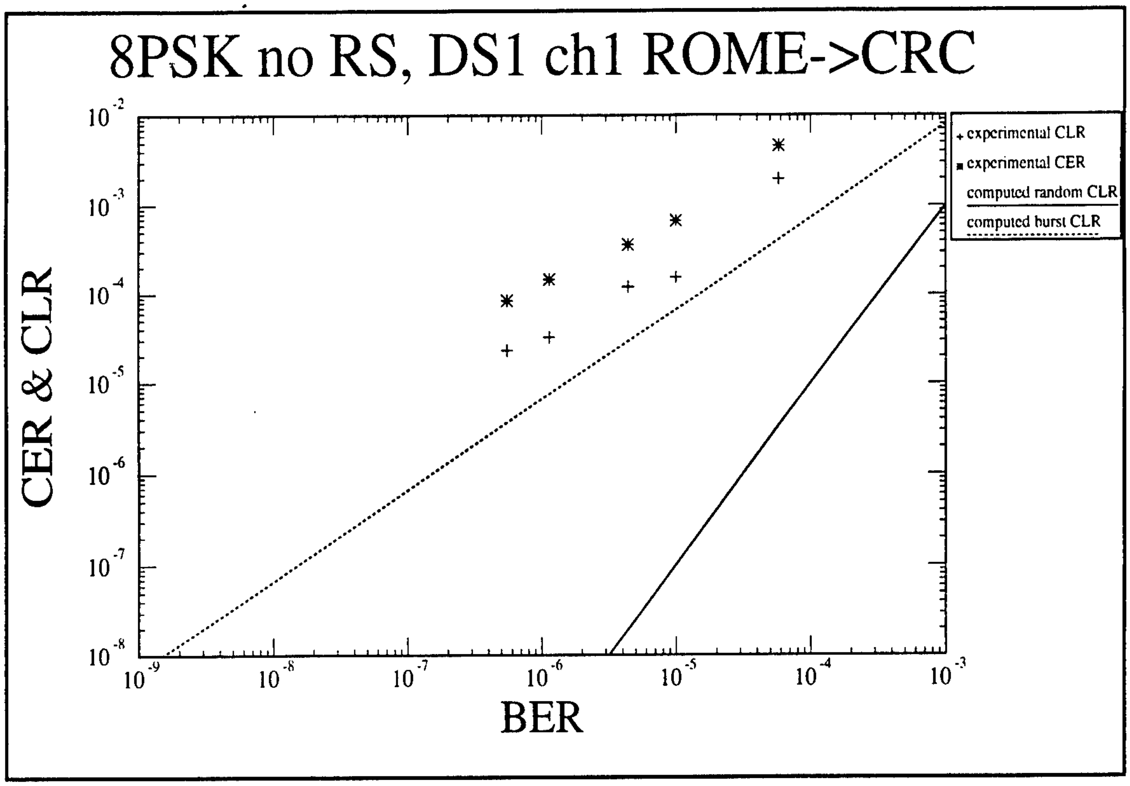

Figure 22: 8PSK no RS subchannels DS1 channel 1 Rome -> CRC

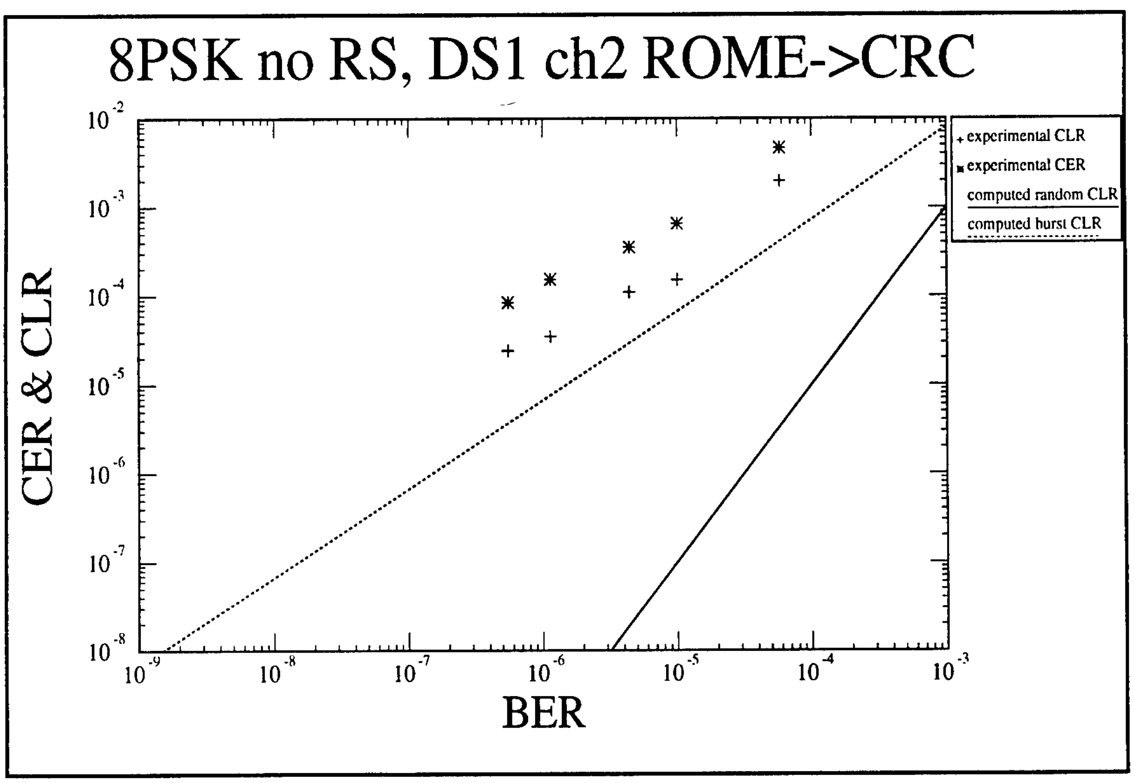

Figure 23: 8PSK no RS subchannels DS1 channel 2 Rome -> CRC

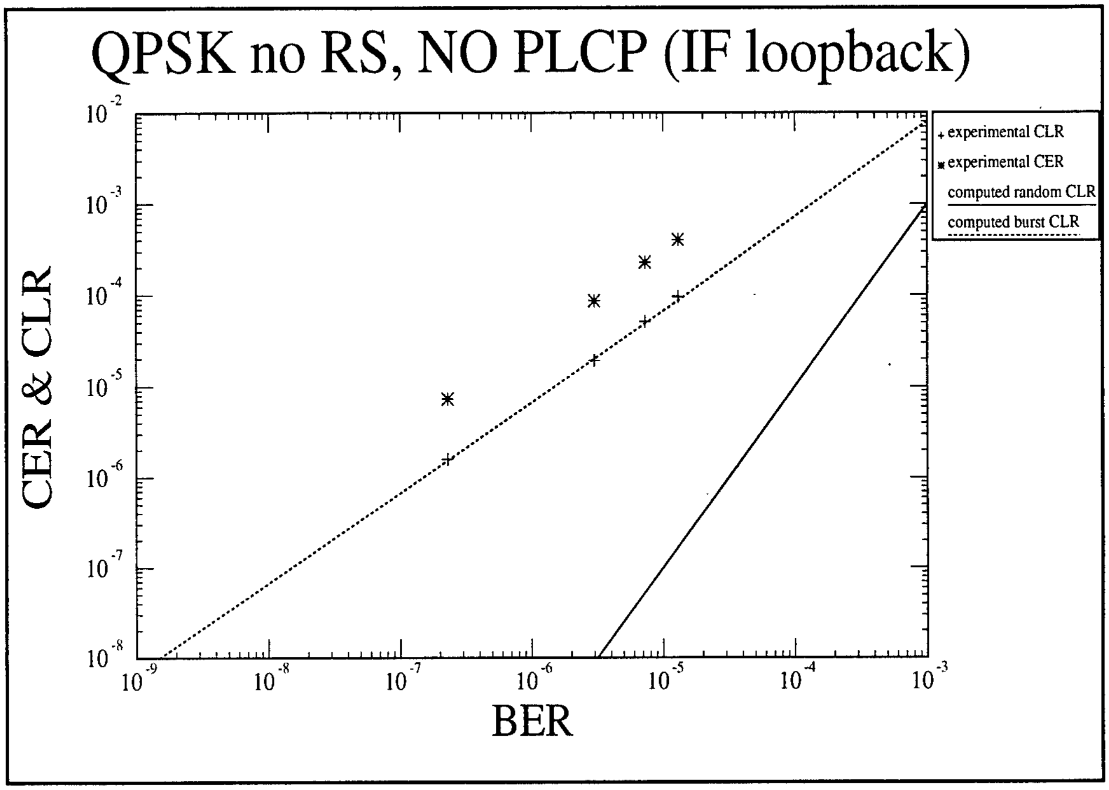

Figure 24: QPSK no RS, No PLCP IF loopback

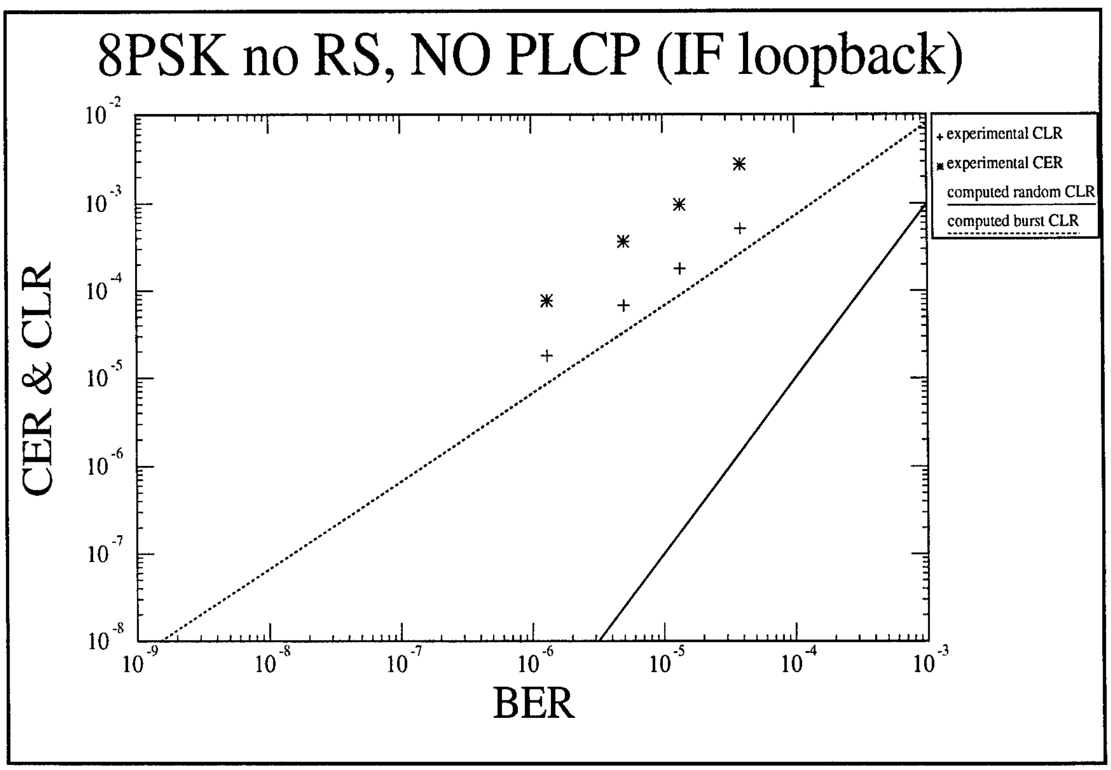

Figure 25: 8PSK no RS, No PLCP IF loopback

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in Section 8) Communications Research Centre 3701 Carling Av. P.O. box 11490 St. H Ottawa, Ont. K2H 8S2	2. SECURITY CLASSIFICATION (overall security classification of the document including special terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title)
ACCORD Broadband ATM satellite Experiment (BASE) -DS3 Ku-band channel (U)

4. AUTHORS (Last name, first name, Middle initial)
Isabelle, Labbe; Louis, Gravel; Gerard, Nourry; Corey, Pike; John, Butterworth; Gretchen, Bivens; Brian, Spink;

5. DATE OF PUBLICATION (month and year of publication of document) December 1997	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 23	6b. NO. OF REFS. (total cited in document) 5

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)
Final Technical Report (CRC-RP-97-007)

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)
DEFENCE RESEARCH ESTABLISHMENT OTTAWA
3701 Carling Av.
Ottawa, Ont.
K1A 0Z4

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) wk unit # 5cb11	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document) CRC RPT 97-007	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned to this document either by the originator or the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)
(x) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify)

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)
UNLIMITED

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

A Broadband ATM satellite Experiment (BASE) was carried out between the Communications Research Centre, Canada and Rome Laboratory, USA during the period of May 95 to March 96. The objective of the experiment was to perform a series of tests to characterize broadband ATM satellite bearers.

This document reports on the first portion of the first phase of the experiment that was conducted in May 95 over the AnikE satellite (Ku-band) . Tests consisted in measurements of ATM Quality of Service (QoS) parameters such as Cell Loss Ratio (CLR) and Cell Error Ratio (CER) as a function of Bit Error Rate (BER). In this report, results are presented for two different modulations (QPSK and 8-PSK) and compared against theoretical curves. Results show good agreement with theory when PLCP framing is not mapped into DS-3 frames. The sub-channels have been found to be coherent with respect to each other. Experimental data further suggest that the broadband channel characteristics are similar to its embedded sub-channels. This implies that the characteristics of the sub-channels could be inferred from the broadband channel or that sub-channels results could be extrapolated to broadband channel results.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

ATM over satellite
Wireless ATM characterization
ATM satellite experiment